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Preliminary Grazing Studies with Rumen-Fistulated Steers at Selected Nuclear-Test Sites

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The greatest variety and concentrations of gamma-emitting radionuclides were present in the ingesta from the Cabriolet-Palanquin Site. The highest levels of Plutonium-238 and -239 were found at the Clean Slate II Site. Strontium-90 levels were highest at the Smoky Site while tritium levels were highest at the Schooner Site.

Each site's carrying capacity for grazing animals was determined. Food habit analyses were also performed for each animal. These data plus the radionuclide data were considered in the recommendation that the Cabriolet-Palanquin Site be selected for any future long-term grazing studies.

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Beef cattle	Fistulated steers	98 E
Range survey	Animal units months	98 D
Fallout	Animal uptake	68 F
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PRELIMINARY GRAZING STUDIES WITH RUMEN-FISTULATED STEERS AT SELECTED NUCLEAR-TEST SITES

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The greatest variety and concentrations of gamma-emitting radionuclides were present in the ingesta from the Cabriolet-Palanquin Site. The highest levels of plutonium-238 and -239 were found at the Clean Slate II Site. Strontium-90 levels were highest at the Smoky Site while tritium levels were highest at the Schooner Site.

Each site's carrying capacity for grazing animals was determined. Food habit analyses were also performed for each animal. These data plus the radionuclide data were considered in the recommendation that the Cabriolet-Palanquin Site be selected for any future long-term grazing studies.

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INTRODUCTION

The Nevada Applied Ecology Group (NAEG) is an assembly of scientific and technical personnel organized by the Department of Energy (DOE) to carry out an integrated applied research program to inventory and study the movements of radionuclides in the Nevada Test Site (NTS) environment. Primary interest is in the transuranics with special emphasis on plutonium.

One facet of the NAEG program was to determine the types and quantities of radionuclides available to grazing animals at a number of nuclear-event sites on the NTS and Tonopah Test Range (TTR). Environmental Protection Agency (EPA) range scientists surveyed the sites to determine their suitability for long-term grazing studies similar to that conducted in Area 13 (Smith, 1979). Six nuclear event sites (see Figure 1 and Table 1) were selected for further investigation and preliminary grazing studies were made with rumen-fistulated steers (steers with a capped tube inserted into a permanent surgical opening into the stomach). Ingesta from the steers were collected and analyzed for radionuclide content and botanical composition.

Figure 1. Approximate locations of nuclear-event sites (■) grazed by rumen-fistulated steers.

TABLE 1. NUCLEAR-EVENT SITES SELECTED FOR THE HUMER-FISTULATED STEER STUDY

...t Name	Date	Location	Type	Purpose	Yield	Remarks
...y	08/31/57	Area 2, NTS	700 ft. tower	Weapons related	44 kt	
Eveny Boy	03/05/62	Buckboard Mesa Area 8, NTS	Crater	Weapons effects	0.42 kt	In basalt.
Smoky... ...te II	05/31/63	Tonopah Test Range	Surface	Storage and transport	Zero	Non-nuclear detonation of a plutonium-bearing weapon. Plutonium was dispersed.
Danny ... ...iolet-	01/26/68	Area 20, NTS	Crater	Plowshare	2.3 kt	Fallout patterns from both events overlapped.
Clean...nquin	04/14/65	Area 20, NTS	Crater	Plowshare	4.3 kt	
Slat... ...	03/12/68	Chukar Mesa, Area 30, NTS	Crater	Plowshare	5.4 kt	Rowcharge experiment in basalt. Simultaneous detonations.
Cabri... Pala...ner	12/08/68	Area 20, NTS	Crater	Plowshare	35 kt	In layered tuffaceous medium.
Buggy...						
Schoo...						

RANGE SURVEY METHODS

The vegetation within and adjacent to each grazing area, with the exception of the Buggy and Schooner sites, was identified by, species and described as outlined in the U.S. Bureau of Land Management's Ocular Reconnaissance Forage Survey Handbook (1963). The survey methods used were based on existing correlations between vegetative growth and local soil conditions. This system involves the identification of specific plant groups by structural features, taxonomic unity, and life forms.

Within each of the four grazing sites surveyed the percentage ground cover and the percentage species composition were determined. The measurements of these two parameters were accomplished by using line transects in which plant species were identified and tabulated as they occurred along a line. This method was rapid and gave accurate information provided the vegetation had the same growth form and the same general crown diameter. It was particularly useful in dense stands of scrubby vegetation.

A 100-foot steel tape measure was used as the line. The tape was suspended 2 inches above the crown height of the vegetation by the use of pre-cut wooden stakes driven into the ground at the tape ends. Sampling points were located at 1-inch intervals along this tape. At each interval plant species were tabulated if touched by a line perpendicular from the tape at each sampling point.

In addition to the vegetative descriptions, the investigators calculated year-long carrying capacity for cattle and sheep within the vicinity of each grazing site. Carrying capacities were obtained by using the percentage composition and ground cover values obtained from the line transects. Also, a forage value was assigned for each identified species. These forage values reflect a particular species palatability, its nutritive value per animal type, and the stem-leaf utilization ratio per season of use. Additional information concerning this method of rangeland livestock inventory is presented by Stoddart and Smith (1955).

EXPERIMENTAL DESIGN

General Procedures

During the late spring and early summer months of 1978, two rumen-fistulated steers were allowed to graze at each of the selected nuclear-event sites (Table 2). Prior to leaving the Area 15 Farm where they were normally kept, the steers' rumens were completely emptied of all ingesta and the rumens were washed at least twice. The steers were then taken to the study site and either released to graze freely within a fenced area or were tethered on 100-ft ropes staked to the ground. The grazing sites were on the hot line as determined by radiation surveys by the Reynolds Electrical and Engineering Company (REECo) RAD-Safe organization. After a sufficient grazing period (4-25 hours) the steers were corraled and all ingesta removed.

The ingesta was separated into fluid and solid components by straining through cheese cloth and any reticulum sediment collected. The fractions were then divided into various samples and handled as described below. Any surplus ingesta (in excess of 1 kilogram for each of the solid and fluid components) was discarded at the site. The steers were then returned to Area 15 for decontamination procedures.

Rumen solid samples were analyzed by gamma spectrometry for gamma-emitting radionuclides and by microscopy for botanical composition. All three ingesta fractions were analyzed by radiochemical techniques for plutonium, americium and strontium. Rumen fluid samples were analyzed for tritium.

Radiation Safety Procedures

All personnel involved in the handling and sampling of the steers at the nuclear site were accompanied by a certified monitor. Appropriate protective clothing (anti-contamination coveralls, gloves, rubber boots, etc.) were worn. Disposable obstetrical sleeves and rubber gloves were worn to remove the ingesta.

All contaminated clothing was placed in plastic bags and returned to the REECo RAD-Safe laundry facility for decontamination. Solid wastes from the sample collection and preparation procedures were placed in plastic-lined 55-gallon drums and disposed of as radioactive waste. Upon return to the Area 15 farm the steers and any contaminated equipment were repeatedly washed with a high-pressure spray in pens that drained into a liquid radioactive waste

TABLE 2. NUCLEAR SITE GRAZING INFORMATION

Site Name	Date and Hours Grazed	Sampling Notes*
Clean Slate II	1200 hours 5/4/78 to 1200 hours 5/5/78	Released in fenced area around ground zero. Water available. Trouble catching steers. Good samples, no reticulum sediment samples.
Palanquin-Cabriolet	1000 to 1400 hours 5/30/78	Tied with 100-ft ropes to corner post and gate post of fenced fallout area - good samples. No reticulum sediment samples.
Smoky	1000 to 1400 hours 06/08/78	Tied with 100-ft ropes to tower posts. Mostly dry cheat grass. Poor sample #912
Danny Boy	1230 hours 6/21/78 to 1330 hours 6/22/78	Tied to 100-ft ropes. Had water available. #913 sample was very dry.
Buggy	1130 hours 6/28/78 to 1230 hours 6/29/78	Tied to 100-ft ropes, water available. Good samples with much Indian Rice Grass.
Schooner	1200 hours 7/5/78 to 1300 hours 7/6/78	Tied to 100-ft ropes. Water available. #912 had poor sample, #913 had a very dry sample. No reticulum sediment samples.

* #912 and #913 were rumen-fistulated steers.

tank. The adequacy of decontamination procedures was determined by certified monitors under the direction of the Radiation Safety Office of the Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV).

Sample Preparation, Storage and Transportation Procedures

While in the field, approximately 1-kilogram portions of rumen fluid and of rumen solids selected for plutonium, americium, and strontium analyses were each sealed in a 1-gallon paint can lined with a plastic bag. Reticulum

sediment samples, when available, were sealed in 200-ml containers. These samples were then stored in freezers at the Area 15 Farm until transported to the analytical laboratories.

Unpreserved 200-ml samples of rumen fluid were collected for tritium analyses. Samples of the rumen solids for gamma analyses were preserved with 10 percent buffered formaldehyde and sealed in 200-ml cans. Samples of rumen solids for botanical analyses were placed in 400-ml containers and preserved by freezing. All final sample preparations were done within the controlled zone of the Area 15 Farm facility. Equipment was decontaminated and wastes disposed of in accordance with the radiation safety procedures.

Prior to shipment to the analytical laboratory all 200-ml sample containers were placed in plastic bags within 1-gallon paint cans. All the paint cans were double-bagged and each bag was individually heat sealed. The cans were then sealed in boxes filled with vermiculite. The boxes were labeled and shipped to the analytical laboratory in accordance with Department of Transportation (DOT) regulations and in coordination with REECo Ramatrol.

Quality Assurance Procedures

The ingesta or rumen contents result from the grazing by the study steers over a fairly wide territory which is contaminated to varying degrees. Individual steers show a decided preference in their grazing habits. Much of the radionuclide contamination results from the ingestion of relatively few highly radioactive or "hot" particles which are not randomly distributed. Therefore, side-by-side samples of ingesta may vary widely in radionuclide content. The "hot" particle contamination, plus the coarseness of the vegetation ingested prevent homogenization of the samples by standard laboratory methods. To provide samples for quality assurance analyses, samples of rumen fluid and rumen solids were collected from rumen-fistulated steers that were eating alfalfa hay at the Area 15 Farm. Several samples of each ingesta fraction were submitted for plutonium, americium, and strontium analyses to the analytical laboratory as blank samples to determine background levels and as a check on the consistency of analysis by the laboratory. Other samples of each type were spiked with a specified amount of plutonium-239, americium-241, and strontium-90. Rumen fluid samples were also collected for blank samples and for spiking with tritium. These samples served to check the proficiency of the laboratory for these types of analyses.

All of these quality assurance samples were labeled and handled in the same manner as the field samples. Approximate activity levels were indicated to the analytical laboratory. The results are presented in Appendix Table 1.

ANALYTICAL METHODS

Samples from Clean Slate II were analyzed for tritium and gamma-emitting radionuclide concentrations by the EMSL-LV. The analyses of all other samples were performed by the Albuquerque laboratory of the Eberline Instrument Corporation (EIC). As a proficiency crosscheck, both laboratories performed gamma analyses on the same rumen solid samples collected from the other five sites.

Samples submitted to EMSL-LV for detection of gamma-emitting radionuclides were analyzed for 1,200 minutes on lithium drifted germanium detectors calibrated to approximately 0.5 kiloelectronvolts (KeV) per channel in the 40-KeV to 2-megaelectronvolt (MeV) range. The detectors were connected to a computer based gamma spectrometry system for spectral data accumulation and analyses. Those samples analyzed by EIC were counted for 100, 400 or 1,000 minutes, on a gamma spectrometry system with an energy range of 30-KeV to 2.1-MeV.

Samples for plutonium, americium, and strontium analyses were prepared by ashing. Plutonium and americium were analyzed by alpha spectrometry using plutonium-236 and americium-243 as internal tracers. Details of the analytical procedures have been published by Talvitie (1971, 1972), Wish and Rowell (1956), Mitchel (1960), Hagen and Arrhenius (1963), Major *et al.* (1975), Sills *et al.* (1979) and Filer (1974). Analytical procedures used for strontium and tritium analyses are described by Johns *et al.* (1979).

The activity values for plutonium-239 listed in this report actually are the sum of the individual isotopic activities of plutonium-239 and 240. The alpha emissions of these two isotopes cannot be separately identified (resolved) by alpha spectrometric analysis (Bernhardt, 1976).

All data are reported with the 95 percent confidence level counting error and are decay corrected to time of sample collection. Results which show a net sample activity less than the miniumum detectable activity are so reported. The minimum detectable activities are defined by Johns *et al.* (1979).

Botanical analyses of the rumen-content samples were done by washing random aliquots of the ingesta with water. After washing, the samples were placed in a shallow pan and suspended in approximately 200 ml of water. Identification of the vegetation was completed by examining each fragment with the aid of a binocular microscope. Following the identification, a visual estimate of the percentage composition for each species was made and recorded. The shrubs and forbs were identified according to Munz and Keck (1965) and McMinn (1964) and the grasses according to Hitchcock (1950).

RESULTS AND DISCUSSION

Nuclear Site Vegetation

All of the grazing sites shown on Figure 1 lie within the Great Basin Desert of southern and central Nevada. All are situated extremely close to the vegetative transition between the hot Mojave Desert to the south and the cold Great Basin desert to the north. This is especially true of the Clean Slate II Site.

This transition zone, as described by Beatley (1975) and Wallace and Romney (1972), lies just south of Beatty on the western edge of the NTS and runs in a northeast direction, exiting the NTS near the midpoint of the eastern boundary. Numerous investigations have been conducted concerning the floral and fauna distributions in the vicinity of this vegetational transition zone. Most notable of these include studies by Meyer (1978), Beatley (1976), Wallace and Romney (1972), and Bradley (1967). Such studies have been summarized by O'Farrell and Emery (1976). Because of the close proximity of these grazing sites to this zone, floristic elements of each area exist on all of the grazing sites.

The vegetative descriptions and carrying capacities of the Clean Slate II, Smoky, Cabriolet-Palanquin, and Danny Boy Site vicinities are shown in Appendix Tables 2-5. With the exception of the Clean Slate II Site, which was dominated by grasses (Appendix Table 2), all were dominated by shrubs. In the vicinity of each site a fairly diverse annual flora existed as exhibited by the numerous grass and forb species. The species abundance of these two vegetative types was enhanced by the soil-surface disturbance caused by the nuclear detonations.

Forty-nine different plant species were observed and identified on the surveyed grazing sites. These species and their corresponding common name are shown in Appendix Table 6. The greatest number of species per plant type observed was forbs, which accounted for 21 species. Shrubs, the second most populous group, were represented by 20 species, followed by grasses with 8 species. These species were observed during the summer months of June, July, and August. As a result, a number of plants native to the site, primarily winter annuals, forbs, and grasses are not included in this list. One forb, *Erodium* sp. and one shrub, *Purshia glandulosa* were found in ingesta but were not identified in range surveys.

Food Habits of the Grazing Steers

The results of the botanical analyses of the rumen ingesta collected from each steer after grazing each nuclear site are shown in Appendix Table 7. These data are similar to previously reported food habit investigations by

Smith *et al.* (1972) and Smith *et al.* (1968), and show that during the summer months, especially during June and July, grasses are the preferred forage. Indian Rice Grass, which exceeded 50.0 percent of the diet for seven of the twelve grazing animal days, contributed 47.7 percent of the total average ingested diet. Other important grasses included squirrel tail and cheat grass which contributed 28.1 and 11.1 percent of the diet, respectively.

Forbs, which can be a significant portion of a grazing animal's diet, depending upon available moisture and the stages of vegetative growth (Smith *et al.* 1972), were not a major constituent of the diet for any of the steers during this study. The dominant identified forb was buckwheat followed by thistle, which contributed 0.4 and 0.3 percent of the total average diet.

Shrubs contributed 4.2 percent of the ingested vegetation and included six identified species. The dominant species was 4-winged saltbush, which contributed only 3.0 percent of the diet and was found in ingesta at only three of the six grazing sites.

Quality Assurance Data

Gamma spectrometry data (Table 3) from samples analyzed by both EMSL-LV and EIC show exceptionally close agreement. The quality assurance data (Appendix 1) indicate that EIC's strontium-90 and tritium analyses were generally reliable. The percent deviations (defined as the percent difference between activity detected and activity added) for tritium analyses ranged from 0%-19% while those for strontium-90 analyses ranged from 6.6%-39% with one exception of 171%. However, the percent deviations for plutonium-239 analyses of rumen fluids and for americium-241 analyses in rumen solids were in poor agreement. The plutonium-239 percent deviations ranged from 0% to 175% (43% average) and for the americium-241 deviations ranged from 0% to 155% (average 51%). These deviations may be explained in part by the fact that the quality assurance samples were analyzed in EIC's intermediate-level laboratory, although most of the spiked samples actually contained low-level concentrations. These apparent deviations in the consistency of analyses had no significant effect on the basic conclusions of this report.

Gamma-Emitting Radionuclides

The gamma-emitting radionuclides detected in the ingesta from rumen-fistulated steers that grazed each of the six nuclear sites are listed in Table 3. Other than the naturally-occurring potassium-40, cesium-137 was the radionuclide most consistently detected. Potassium-40 was the only radionuclide found in the ingesta from the Clean Slate II Site. However, this was not unexpected as no nuclear detonation had occurred at that site.

Ingesta from the Cabriolet-Palanquin Site contained the greatest variety and concentrations of gamma-emitting radionuclides. This was the only site from which rhodium-102 and -102m, cobalt-60, and europium-152 were reported in

TABLE 3. GAMMA-EMITTING RADIONUCLIDE CONCENTRATIONS* IN RUMEN CONTENTS FROM RUMEN-FISTULATED STEERS GRAZING SELECTED NUCLEAR-SITES

STEER NUMBER	SITE	ANALYTICAL LABORATORY	Cs-137	Co-60	K-40	Co-57	Rh-102 Rh-102m	Eu-152	Eu-155	Ce-144	Eu-154
912	Clean Slate II	EPA	---	---	5.7±0.2	---	---	---	---	---	---
913	Clean Slate II	EPA	---	---	5.5±0.5	---	---	---	---	---	---
912	Cabriolet-Palanquin	EPA	0.1±0.02	0.3±0.03	2.8±0.02	0.05±0.02	0.05±0.02	0.07±0.06	---	---	---
		EIC	0.3±0.1	0.5±0.1	2.6±0.4	0.06±0.01	0.05±0.01	<0.1	<0.1	<0.1	<0.1
913	Cabriolet-Palanquin	EPA	0.99±0.05	4.3±0.1	3.2±0.4	0.7±0.05	0.4±0.04	0.1±0.02	0.4±0.07	---	0.36±0.14
		EIC	1.0±0.1	4.4±0.4	2.3±0.2	<0.1	0.4±0.1	1.0±0.1	0.3±0.1	<0.1	<0.1
912	Smoky	EPA	0.09±0.02	0.06±0.02	0.6±0.2	0.05±0.04	---	0.6±0.06	---	---	---
		EIC	0.10±0.01	0.05±0.01	1.0±0.1	<0.1	<0.1	0.6±0.1	<0.1	<0.1	<0.1
913	Smoky	EPA	0.04±0.01	---	2.0±0.2	---	---	---	---	---	---
		EIC	0.07±0.01	<0.1	1.7±0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
912	Danny Boy	EPA	0.10±0.02	---	2.3±0.2	---	---	---	---	---	---
		EIC	0.09±0.01	<0.1	1.0±0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
913	Danny Boy	EPA	0.07±0.05	---	2.8±0.3	---	---	---	---	---	---
		EIC	0.2±0.1	<0.1	3.4±0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
912	Buggy	EPA	0.05±0.02	---	3.2±0.3	---	---	---	---	0.38±0.22	---
		EIC	0.04±0.01	<0.1	1.6±0.2	<0.1	<0.1	<0.1	<0.1	0.20±0.04	<0.1
913	Buggy	EPA	0.05±0.01	---	3.3±0.3	---	---	---	---	---	---
		EIC	<0.1	<0.1	2.5±0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
912	Schooner	EPA	0.04±0.03	0.15±0.04	4.5±0.4	0.25±0.05	---	0.12±0.05	0.06±0.04	---	0.18±0.13
		EIC	0.04±0.01	0.08±0.01	2.0±0.2	<0.1	<0.1	<0.1	0.08±0.01	<0.1	0.17±0.02
913	Schooner	EPA	0.025±0.017	0.09±0.03	3.6±0.3	0.23±0.04	---	---	---	---	---
		EIC	<0.1	0.12±0.02	3.3±0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

* Results are reported in pCi/g of wet weight as of collection date.
--- Not detected
EPA Analyses by EMSL-LV
EIC Analyses by Eberline Instrument Corporation

all ingesta samples. Rhodium-102 and rhodium-102m were not reported in samples collected from any other site. Ingesta samples from the Schooner Site also contained a variety of radionuclides. Cerium-144 was reported from one ingesta sample collected at the Buggy Site.

The Smoky Site samples did not include a very wide inventory of radionuclides, despite its being the only site studied that had been exposed to an atmospheric nuclear detonation. However, 21 years had elapsed between detonation and sampling, and most of the radionuclides originally present had gone through a sufficient number of half-lives so as to be no longer detectable.

Strontium-90

Strontium-90 concentrations in the ingesta (rumen fluid, rumen solids, and reticulum sediment samples) collected from the two steers that grazed the six nuclear sites are listed in Tables 4-9.

Reticulum sediment samples are essentially samples of soil ingested by the steers during the grazing process. Therefore, it is not surprising that the reticulum sediment samples contain concentrations of strontium and other radionuclides that are several orders of magnitude greater than those detected in the rumen solids (primarily plant materials) or rumen fluids (a mixture of water, saliva and digestive juice). Strontium-90 levels were consistently greater in the rumen solid samples than in the rumen fluid samples. The highest concentrations were reported in samples collected from the Smoky atmospheric nuclear detonation site.

Tritium

Samples of rumen fluid collected from each of the steers that grazed the six nuclear sites were analyzed for tritium content. The analytical data are listed in Tables 4-9 and are depicted graphically in Figure 2.

There was little variation in the tritium content between the two samples collected at each site. The values for samples from each site ranged from approximately 400 picocuries per liter (pCi/l) for Clean Slate II to around 3,000 pCi/l in the Schooner Site samples. Levels in the samples from the other sites were generally around 1,000 pCi/l. EIC's minimum detection limit is 1000 pCi/l without tritium enrichment by electrolysis.

Only the Schooner Site samples and one of the Buggy Site samples contained tritium concentrations that exceeded the range of <300 to 1,900 pCi/l of atmospheric moisture found in air samples collected at Beatty, Nevada for the Noble Gas and Tritium Surveillance Network (Nuclear Radiation Assessment Division, 1979). The five highest values came from the Schooner, Buggy, and Cabriolet-Palanquin Sites, which were also the most recent nuclear events (see Table 1).

TABLE 4. PLUTONIUM*, STRONTIUM*, AND TRITIUM** CONCENTRATIONS IN IN INGESTA COLLECTED FROM RUMEN-FISTULATED STEERS GRAZING THE CLEAN SLATE II SITE

Nuclide	Steer No. 912		Steer No. 913	
	Rumen Fluid	Rumen Solids	Rumen Fluid	Rumen Solids
^{238}Pu	15±2.1	200±23	36±4.9	34±8.8
^{239}Pu	1,700±120	13,000±700	2,800±90	3,800±470
^{90}Sr	<18	<41	29±9.2	<48
% ASH	0.95	2.8	1.1	2.8
^{3}H	430±240	NA	<380	NA

* Results reported in pCi/kg (wet weight)
** Results reported in pCi/l
NA Not analyzed

TABLE 5. PLUTONIUM*, AMERICIUM*, STRONTIUM*, AND TRITIUM** CONCENTRATIONS IN INGESTA COLLECTED FROM RUMEN-FISTULATED STEERS GRAZING THE SMOKY SITE

Nuclide	Steer No. 912			Steer No. 913		
	Rumen Fluid	Rumen Solids	Reticulum Sediment	Rumen Fluid	Rumen Solids	Reticulum Sediment
^{238}Pu	1.0±0.26	70±4.2	1,600±100	<0.19	120±4.0	2,200±180
^{239}Pu	41±1.3	420±13	4,800±220	30±1.5	110±4.0	8,500±390
^{241}Am	4.2±1.8	20±5.8	48±30	3.6±1.3	8.7±2.1	<26
^{90}Sr	20±4.9	610±29	360±66	18±4.4	88±6.2	860±160
% ASH	2.6	3.2	37	1.9	1.8	65
^{3}H	1,200±1,100	NA	NA	<1,000	NA	NA

* Results reported in pCi/kg (wet weight)
** Results reported in pCi/l
NA Not analyzed

TABLE 6. PLUTONIUM*, AMERICIUM*, STRONTIUM*, AND TRITIUM** CONCENTRATIONS IN INGESTA COLLECTED FROM RUMEN-FISTULATED STEERS GRAZING THE CABRIOLET-PALANQUIN SITE

Nuclide	Steer No. 912		Steer No. 913	
	Rumen Fluid	Rumen Solids	Rumen Fluid	Rumen Solids
^{238}Pu	13±1.5	9.8±1.5	1.9±0.4	12±1.1
^{239}Pu	58±3.2	55±3.3	13±1.0	58±2.4
^{241}Am	23±4.6	23±3.3	3.1±1.2	23±3.4
^{90}Sr	50±7.4	97±8.3	<3.4	<13
% ASH	1.9	3.0	1.3	2.6
^{3}H	1,300±1,200	NA	<1,000	NA

* Results reported in pCi/kg (wet weight)
** Results reported in pCi/l
NA Not analyzed

TABLE 7. PLUTONIUM*, AMERICIUM*, STRONTIUM*, AND TRITIUM** CONCENTRATIONS IN INGESTA COLLECTED FROM RUMEN-FISTULATED STEERS GRAZING THE DANNY BOY SITE

Nuclide	Steer No. 912			Steer No. 913		
	Rumen Fluid	Rumen Solids	Reticulum Sediment	Rumen Fluid	Rumen Solids	Reticulum Sediment
^{238}Pu	2.4±0.24	17±1.4	650±90	2.6±1.7	9.4±1.1	310±61
^{239}Pu	16±0.71	55±2.3	7,600±350	140±13	78±2.9	4,500±270
^{241}Am	6.3±1.4	13±2.4	130±50	30±8.3	18±6.8	100±40
^{90}Sr	<2.9	100±9.1	6,300±1,200	<23	190±13	8,300±1,300
% ASH	0.8	2.3	12	2.1	3.6	17
^{3}H	<1,000	NA	NA	<1,000	NA	NA

* Results reported in pCi/kg (wet weight)
** Results reported in pCi/l
NA Not analyzed

TABLE 8. PLUTONIUM*, AMERICIUM*, STRONTIUM*, AND TRITIUM** CONCENTRATIONS IN INGESTA COLLECTED FROM RUMEN-FISTULATED STEERS GRAZING THE BUGGY SITE

Nuclide	Steer No. 912			Steer No. 913		
	Rumen Fluid	Rumen Solids	Reticulum Sediment	Rumen Fluid	Rumen Solids	Reticulum Sediment
^{238}Pu	1.7±0.38	24±2.0	1,100±50	7.8±0.78	5.3±0.97	3,000±370
^{239}Pu	3.4±0.51	43±2.8	900±46	11±0.9	17±1.4	15,000±900
^{241}Am	2.2±0.63	5.4±2.3	15±7.2	3.3±0.62	10±3.1	7,300±1,200
^{90}Sr	24±8.6	57±6.0	217±48	27±4.2	78±6.3	12,000±2,800
% ASH	1.3	2.8	12	1.6	2.4	31
^{3}H	1,800±1,200	NA	NA	2,000±1,200	NA	NA

* Results reported in pCi/kg (wet weight)
** Results reported in pCi/l
NA Not analyzed

TABLE 9. PLUTONIUM*, AMERICIUM*, STRONTIUM*, AND TRITIUM** CONCENTRATIONS IN INGESTA COLLECTED FROM RUMEN-FISTULATED STEERS GRAZING THE SCHOONER SITE

Nuclide	Steer No. 912		Steer No. 913	
	Rumen Fluid	Rumen Solids	Rumen Fluid	Rumen Solids
^{238}Pu	2.6±0.5	2.9±0.57	12±0.8	13±1.7
^{239}Pu	2.7±0.5	4.9±0.86	9.4±0.6	15±1.7
^{241}Am	0.43±0.17	1.2±0.86	6.6±2.3	2±1.3
^{90}Sr	12±3.0	33±6.3	13±5.9	60±8.6
% ASH	1.3	2.9	1.5	3.3
^{3}H	2,800±1,200	NA	3,400±1,200	NA

* Results reported in pCi/kg (wet weight)
** Results reported in pCi/l
NA Not analyzed

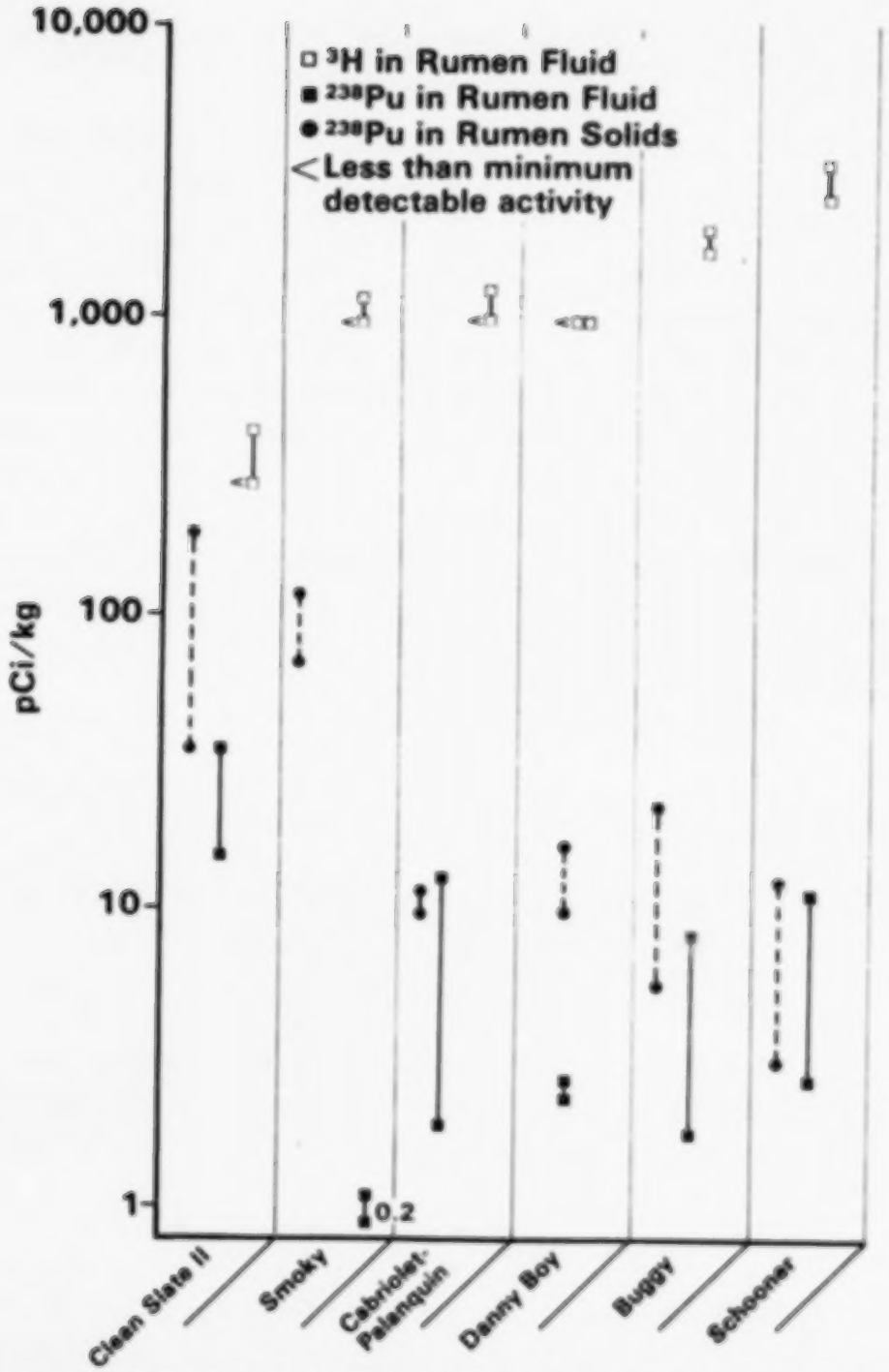

Figure 2. Tritium and plutonium-238 concentrations in ingesta from two rumen-fistulated steers that grazed six nuclear sites.

Plutonium and Americium

All ingesta samples were analyzed for plutonium-238 and -239 and americium-241. The analytical data are listed in Tables 4 through 9 and are depicted graphically in Figures 3 and 4 respectively.

As mentioned previously, the reticulum sediment samples were essentially soil samples. As would be expected, the highest concentrations of plutonium and americium reported in the ingesta from each site were found in this sample fraction.

The highest plutonium levels were found in ingesta samples collected at the Clean Slate II Site. This was expected as the test had consisted of destroying a plutonium-bearing weapon with high explosives resulting in plutonium being dispersed over the site area. The ratio of plutonium-239 to plutonium-238 in the ingesta was highest at this site. Rumen solid samples from the Smoky site contained the second highest concentrations of plutonium-239 reported (Figures 3 and 4).

Clean Slate II samples were not analyzed for americium. Plutonium-239 to americium-141 ratios were calculated for the ingesta from all other sites. These ratios were very consistent at the Cabriolet-Palanquin, Danny Boy, Buggy and Schooner Sites (1.7-7.5) but were considerably higher at the Smoky Site (12.6 and 21).

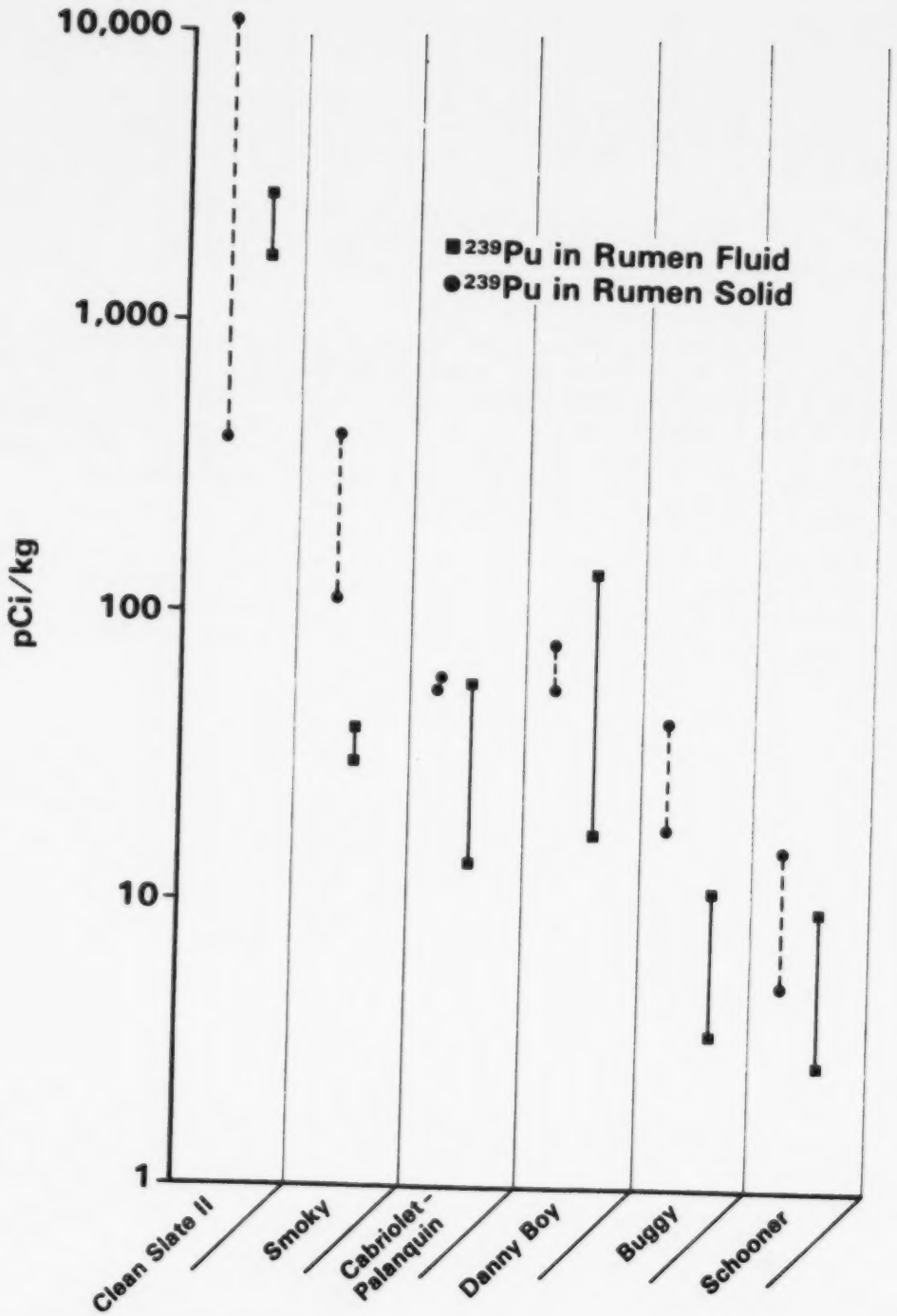

Figure 3. Plutonium-239 concentrations in ingesta from two rumen-fistulated steers that grazed six nuclear sites.

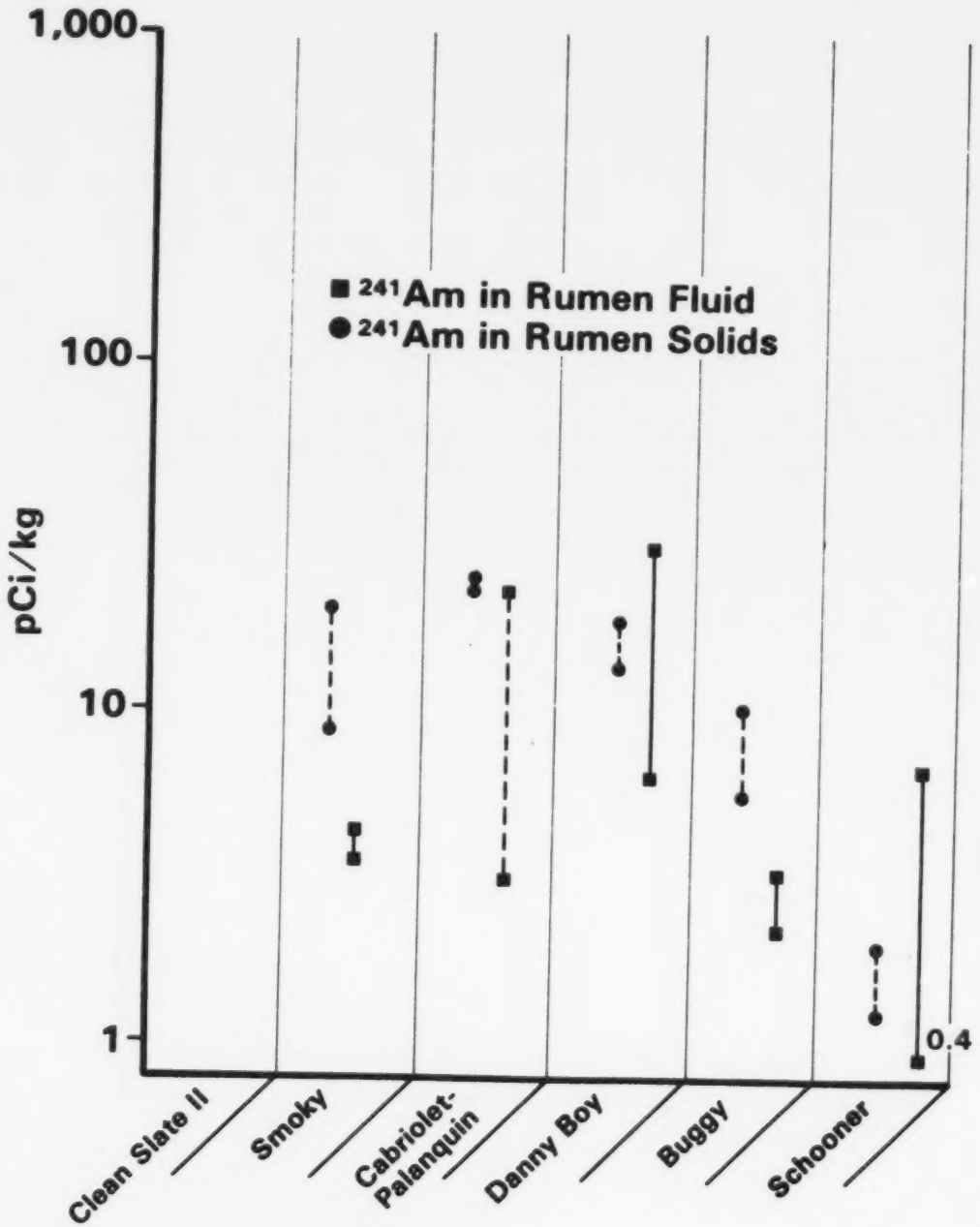

Figure 4. Americium-241 concentrations in ingesta from two rumen-fistulated steers that grazed six nuclear sites.

CONCLUSIONS

Rumen-fistulated steers have been used for many years to provide information on the food habits and nutritive intake of grazing cattle. In this study, they were also used to provide a rapid indication of the available radionuclide inventory of a selected nuclear site. The range transects of vegetative cover indicate whether a range has enough carrying capacity to support sufficient numbers of cattle to provide meaningful data for a long-term grazing study.

The greatest variety and highest concentrations of gamma-emitting radionuclides were present in ingesta samples collected from steers that grazed the Cabriolet-Palanquin Site. Ingesta from this site also contained significant levels of tritium, strontium-90, americium-141, plutonium-238, and plutonium-239. Moreover, the Cabriolet-Palanquin Site has a relatively heavy vegetative cover of palatable perennial plants, is fenced, and is reasonably accessible. For these reasons, it is recommended that this site be selected for any future long-term grazing studies.

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APPENDIX TABLE 1. QUALITY ASSURANCE RESULTS

Sample Type*	Wet Weight (g)	Nuclide	Activity Added (pCi/kg) (pCi/l ^{3}H)	Activity Reported (pCi/kg) (pCi/l ^{3}H)	Percent Deviation**
Rumen fluid	1628	^{239}Pu	0	1.3 ± 0.36	---
		^{241}Am	0	2.2 ± 1.9	---
		^{90}Sr	0	<11.9	---
Rumen fluid	1941	^{239}Pu	0	5.1 ± 0.88	---
		^{241}Am	0	0.66 ± 0.44	---
		^{90}Sr	0	<4.0	---
Rumen fluid	1756	^{239}Pu	0	0.4 ± 0.2	---
		^{241}Am	0	<0.4	---
		^{90}Sr	0	<3.6	---
Rumen fluid	1969	^{239}Pu	110	43 ± 3.9	61
		^{241}Am	20	17 ± 3.3	15
		^{90}Sr	270	240 ± 11	10
Rumen fluid	1806	^{239}Pu	120	330 ± 63	175
		^{241}Am	22	15 ± 2.4	32
		^{90}Sr	290	230 ± 16	21
Rumen fluid	1531	^{239}Pu	40	42 ± 5.9	5
		^{241}Am	6.6	5.9 ± 1.3	11
		^{90}Sr	140	86 ± 12	39
Rumen fluid	1649	^{239}Pu	37	33 ± 3.2	11
		^{241}Am	6.1	5.6 ± 1.4	8.2
		^{90}Sr	134	83 ± 13	38
Rumen fluid	1875	^{239}Pu	7.3	7.3 ± 0.86	0
		^{241}Am	3.5	3.2 ± 1.7	8.6
		^{90}Sr	19	23 ± 9.6	21
Rumen fluid	1560	^{239}Pu	8.6	8.0 ± 1.2	7
		^{241}Am	4.2	3.1 ± 1.0	26
		^{90}Sr	22	29 ± 7	32
Rumen solids	1426	^{239}Pu	0	0.86 ± 0.43	---
		^{241}Am	0	1.3 ± 1.1	---
		^{90}Sr	0	37 ± 11	---
Rumen solids	1393	^{239}Pu	0	1.1 ± 0.2	---
		^{241}Am	0	3.1 ± 1.1	---
		^{90}Sr	0	36 ± 11	---

(continued)

APPENDIX TABLE 1. (Continued)

Sample Type*	Wet Weight (g)	Nuclide	Activity Added (pCi/kg) (pCi/l ^{3}H)	Activity Reported (pCi/kg) (pCi/l ^{3}H)	Percent Deviation**
Rumen solids	1357	^{239}Pu	0	0.67 ± 0.22	---
		^{241}Am	0	<0.45	---
		^{90}Sr	0	29 ± 8.8	---
Rumen solids	1123	^{239}Pu	180	110 ± 9	39
		^{241}Am	41	39 ± 5.5	5
		^{90}Sr	320	299 ± 20	6.6
Rumen solids	1254	^{239}Pu	160	97 ± 13	39
		^{241}Am	36	32 ± 8.3	11
		^{90}Sr	280	311 ± 22	11
Rumen solids	1339	^{239}Pu	33	30 ± 2.9	9
		^{241}Am	6.3	7.3 ± 1.5	16
		^{90}Sr	130	97 ± 16	25
Rumen solids	1510	^{239}Pu	29	30 ± 3.2	3.4
		^{241}Am	5.6	5.6 ± 1.9	0
		^{90}Sr	120	96 ± 13	20
Rumen solids	1193	^{239}Pu	9.2	7.9 ± 1.1	14
		^{241}Am	4.7	12 ± 3.2	155
		^{90}Sr	37	47 ± 10	27
Rumen solids	1388	^{239}Pu	7.9	11 ± 2.4	39
		^{241}Am	4	8.8 ± 3.1	120
		^{90}Sr	32	87 ± 17	171
Rumen fluid	75 ml	^{3}H	7,800	6,300 ± 1,300	19
Rumen fluid	100 ml	^{3}H	33,000	28,000 ± 2,000	15
Rumen fluid	90 ml	^{3}H	9,500	9,500 ± 1,400	0
Rumen fluid	100 ml	^{3}H	0	1,200 ± 1,100	---
Rumen fluid	75 ml	^{3}H	35,000	30,000 ± 2,000	14
Rumen fluid	75 ml	^{3}H	0	<1,000	---
Rumen fluid	100 ml	^{3}H	10,000	9,400 ± 1,400	6
Rumen fluid	110 ml	^{3}H	5,000	5,700 ± 1,300	14

* Rumen fluid and rumen solids collected from rumen fistulated steers which were fed alfalfa at the Area 15 farm.

** % deviation = $\frac{(x-u)}{u} \times 100$

where x = activity reported

u = activity added

APPENDIX TABLE 2. GROUND COVER AND THE PERCENTAGE COMPOSITION OF PLANT SPECIES FOUND IN THE VICINITY OF THE CLEAN SLATE II GRAZING SITE

Species	Ground Cover (%)	Composition (%)
Oryzopsis hymenoides	4.0	20.0
Hilaria jamesii	6.6	33.0
Stipa sp.	Trace	Trace
Sitanion hystrix	Trace	Trace
	Trace	Trace
Total grasses	10.6	53.0
Unidentified forbs	0.4	2.0
Sphaeralcea sp.	0.4	2.0
Eriogonum sp.	0.2	1.0
Halogeton glomeratus	0.2	1.0
Stanley pinnata	Trace	Trace
Linum sp.	Trace	Trace
Total forbs	1.2	6.0
Artemisia nova	2.2	11.0
Atriplex canescens	0.4	2.0
Atriplex confertifolia	2.9	14.0
Eurotia lanata	2.5	13.0
Grayia spinosa	Trace	Trace
Artemisia tridentata	Trace	Trace
Chrysothamnus viscidiflorus	0.2	1.0
Tetradymia glabrata	Trace	Trace
Total shrubs	8.2	41.0

Trace - less than 0.1%
Carrying capacity - Cattle - 9.7 AUM (Animal Units Month)
Sheep - 11.1 AUM

APPENDIX TABLE 3. GROUND COVER AND THE PERCENTAGE COMPOSITION OF PLANT SPECIES FOUND IN THE VICINITY OF THE SMOKY GRAZING SITE

Species	Ground Cover (%)	Composition (%)
Oryzopsis hymenoides	Trace	Trace
Hilaria jamesii	Trace	Trace
Stipa speciosa	4.2	10.2
Sitanion hystrix	Trace	Trace
Tridens pulchella	Trace	Trace
Total grasses	4.2	10.2
Eriogonum nidularium	Trace	Trace
Salsola kali	Trace	Trace
Sphaeralcea ambigua	Trace	Trace
Euphorbia sp.	Trace	Trace
Descurania sp.	0.2	0.5
Astragalus sp.	Trace	Trace
Total forbs	0.2	0.5
Coleogyne ramosissima	14.4	35.0
Ephedra nevadensis	2.7	6.8
Chrysothamnus viscidiflorus	Trace	Trace
Grayia spinosa	7.3	17.8
Haplopappus cooperi	6.9	16.7
Hymenoclea salsola	3.5	9.0
Eurotia lanata	0.9	2.2
Lycium andersonii	0.8	1.8
Cowania mexicana	Trace	Trace
Encelia virginensis	Trace	Trace
Total shrubs	36.5	89.3

Trace - less than 0.1%
Carrying capacity - Cattle - 11.1 AUM
Sheep - 11.1 AUM

APPENDIX TABLE 4. GROUND COVER AND THE PERCENTAGE COMPOSITION OF PLANT SPECIES FOUND IN THE VICINITY OF THE CABRIOLET-PALANQUIN GRAZING SITE

Species	Ground Cover (%)	Composition (%)
Sitanion hystrix	2.9	10.0
Bromus tectorum	2.1	7.0
Oryzopsis hymenoides	1.8	6.0
Hilaria jamesii	1.5	5.0
Stipa speciosa	0.8	3.0
Aristida sp.	Trace	Trace
Total grasses	9.1	31.0
Salsola sp.	0.2	1.0
Unidentified forbs	0.2	1.0
Astragalus sp.	Trace	Trace
Sphaeralcea sp.	Trace	Trace
Eriogonum sp.	Trace	Trace
Opuntia sp.	Trace	Trace
Total forbs	0.4	2.0
Ephedra nevadensis	4.6	16.0
Artemisia tridentata	3.9	13.0
Grayia spinosa	2.6	9.0
Gutierrezia sp.	2.1	7.0
Chrysothamnus viscidiflorus	1.8	6.0
Unidentified shrubs	1.1	4.0
Chrysothamnus nauseosus	0.8	3.0
Eurotia lanata	0.8	3.0
Atriplex canescens	0.6	2.0
Eriogonum sp.	0.3	1.0
Cowania mexicana	0.3	1.0
Lycium andersonii	0.3	1.0
Juniperus osteosperma	0.3	1.0
Ephedra viridis	Trace	Trace
Total shrubs	19.5	66.0

Trace - less than 0.1%
Carrying capacity - Cattle - 9.7 AUM
Sheep - 8.7 AUM

APPENDIX TABLE 5. GROUND COVER AND THE PERCENTAGE COMPOSITION OF PLANT SPECIES FOUND IN THE VICINITY OF THE DANNY BOY GRAZING SITE

Species	Ground Cover (%)	Composition (%)
Sitanion hystrix	0.9	2.9
Oryzopsis hymenoides	0.8	2.8
Hilaria jamesii	0.5	1.6
Stipa speciosa	0.4	1.3
Bromus tectorum	0.2	0.5
Poa sp.	Trace	Trace
Total grasses	2.8	9.1
Eriogonum sp.	0.8	3.0
Unidentified forbs	0.3	1.4
Sphaeralcea ambigua	0.2	0.8
Descurainia pinnata	0.2	0.8
Salsola sp.	0.1	0.1
Aster sp.	0.1	0.1
Senecio sp.	0.1	0.1
Euphorbia sp.	0.1	0.1
Gilia aremica	0.1	0.1
Amsinckia sp.	Trace	Trace
Oenothera sp.	Trace	Trace
Astragalus lentiginosus	Trace	Trace
Total forbs	2.0	6.5
Artemisia tridentata	10.2	33.9
Ephedra nevadensis	3.6	13.2
Atriplex canescens	3.0	11.9
Chrysothamnus viscidiflorus	1.5	6.6
Cowania mexicana	1.7	5.8
Grayia spinosa	1.5	5.6
Tetradymia sp.	0.6	2.6
Chrysothamnus nauseosus	0.5	1.9
Ephedra viridis	0.4	1.3
Eurotia lanata	0.2	0.9
Artemisia nova	0.2	0.7
Total shrubs	23.4	84.4

Trace - less than 0.1%
Carrying capacity - Cattle - 26.0 AUM
Sheep - 26.0 AUM

APPENDIX TABLE 6. PLANT SPECIES IDENTIFIED ON THE NUCLEAR GRAZING SITES

Genus Species	Common names
Grasses	
Oryzopsis hymenoides	Indian Rice Grass
Hilaria jamesii	Galleta
Stipa speciosa	Desert needle grass
Sitanion hystrix	Squirrel tail
Tridens pulchella	Fluff grass
Stipa sp.	Needle grass
Bromus tectorum	Cheatgrass
Aristida sp.	Three Awn
Forbs	
Eriogonum nidularium	Buckwheat
Salsola kali	Russian thistle
Sphaeralcea ambigua	Globe mallow
Euphorbia sp.	Spurge
Descurainia sp.	Mustard
Astragalus sp.	Loco weed
Sphaeralcea sp.	Mallow
Eriogonum sp.	Buckwheat
Halogeton glomeratus	Halogeton
Stanleya pinnata	Desert plume
Linum sp.	Flax
Salsola pauleenii	Russian Thistle
Descurainia pinnata	Tansey mustard
Salsola sp.	Russian thistle
Aster sp.	Aster
Senecio sp.	Groundsel
Gilia eramica	Gilia
Amsinckia sp.	Fiddle neck
Oenothera sp.	Primrose
Astragalus lentiginosus	Mottled locoweed
Opuntia sp.	Beaver tail
Erodium sp.	Desert Herons Bill
Shrubs	
Encelia virginensis	Encelia
Artemisia tridentata	Big sagebrush
Ephedra nevadensis	Nevada joint fir
Artiplex canescens	4-winged saltbrush
Chrysothamnus viscidiflorus	Rabbitbrush
Cowania mexicana	Cliff rose
Grayia spinosa	Spiny hop-sage
Purshia glandulosa	Bitter brush

(continued)

APPENDIX TABLE 6. (Continued)

Genus Species	Common Names
Shrubs	
Tetradymia sp.	Horse brush
Chrysothamnus nauseosus	Big rabbitbrush
Ephedra viridis	Mountain joint fir
Eurotia lanata	White sage
Artemisia nova	Black sagebrush
Coleogyne ramosissima	Black brush
Haplopappus cooperi	Golden bush
Hymenoclea salsola	Cheese bush
Lycium andersonii	Thornbush
Atriplex confertifolia	Shadscale
Tetradymia glabrata	Felt thorn
Gutierrezia sp.	Matchweed
Eriogonum sp.	Buckwheat
Juniperus osteosperma	Juniper

APPENDIX TABLE 7. PERCENT BOTANICAL COMPOSITION OF RUMEN INGESTA FROM RUMEN-FISTULATED STEERS THAT GRAZED SIX NUCLEAR SITES

Species	Buggy		Cabriolet-Palanquin		Danny Boy		Clean Slate II		Schooner		Smoky		Total Ingested (%)
	Steer No.		Steer No.		Steer No.		Steer No.		Steer No.		Steer No.		
	912	913	912	913	912	913	912	913	912	913	912	913	
Oryzopsis hymenoides	51.0	14.0	33.0	24.0	91.0	80.0	78.0	74.0	63.0	58.0	4.0	2.0	47.7
Sitanion hystrix	46.0	73.0	67.0	72.0	3.0		5.0	7.0	3.0	9.0	36.0	16.0	28.1
Bromus tectorum		3.0									52.0	78.0	11.1
Unidentified grass	1.0	2.0	Trace	2.0		2.0	1.0	6.0	5.0	1.0	0.0	2.0	2.0
Hilaria jamesii							4.0		22.0	19.0			3.8
Stipa speciosa								3.0		2.0			0.3
Total grasses	98.0	92.0	100.0	98.0	94.0	82.0	88.0	90.0	93.0	89.0	94.0	98.0	93.0
Sphaeralcea sp.	Trace	1.0									2.0		0.3
Unidentified forb	1.0	1.0	Trace	2.0	1.0	2.0	3.0	4.0	2.0	1.0	2.0	2.0	1.7
Erodium sp.	1.0				1.0			1.0	1.0	Trace	1.0	Trace	0.1
Eriogonum sp.	Trace	1.0				1.0			2.0		1.0	Trace	0.4
Salsola paulsenii													0.3
Total forbs	2.0	3.0	Trace	2.0	2.0	3.0	3.0	5.0	5.0	1.0	6.0	2.0	2.8
Atriplex canescens					4.0	12.0	6.0	2.0	2.0	10.0			3.0
Eurotia lanata												Trace	Trace
Artemisia nova										Trace			Trace
Atriplex confertifolia							3.0	3.0					0.5
Ephedra nevadensis						3.0							0.3
Purshia glandulosa		5.0											0.4
Total shrubs	0.0	5.0	0.0	0.0	4.0	15.0	9.0	5.0	2.0	10.0	0.0	Trace	4.2

Trace - less than 0.1%

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